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1. INTRODUCTION[1]

The interdependencies inherent in the structure of international financial flows and international economic activity motivated some of the earliest attempts to develop the basic principles of economics. The theorizing predated A. Smith by decades and has been the subject of almost constant evolution during the intervening centuries. The principles of economic behavior that were isolated by what are now recognized as partial equilibrium theories have been integrated over the years to construct the general competitive model. The overriding power of this model to provide consistency in sets of ideas and theories cannot be denied and, as such, it stands as a remarkable intellectual achievement. However, the accuracy of the model might be challenged in special applications, and the specific quantitative predictions of the model might not be testable in the complicated setting of the naturally occurring world.

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The purpose of the experiments reported below is to explore and measure the accuracy of the basic principles of international finance as captured by the general competitive model. The model is applied to a set of simple laboratory economies that contain some of the complexities about which decades, if not centuries of theorizing, have grappled.

In a sense, the experiments are a test of "proof of principle." Since the world economy is too complicated to permit a clear test of ideas, we do not really know if the interrelationships of imports, exports, and exchange rates, are governed by the operation of the most basic principles implicit in the competitive model. If the general model fails to predict the essence of what is seen in the simple laboratory economies, then one would certainly be suspicious of scholars and practitioners who would claim that the model could be used to predict something that is vastly more complex. Of course, the fact that the model might predict accurately in the laboratory does not mean that it can be applied immediately and confidently to any set of economies that the natural evolution of economies and politics might produce. The basic principles of the model might be operative but they might well be modified by other principles, in addition to those of the competitive model. Principles that might govern the dynamics of a convergence process might be an example. Furthermore, a knowledge of the parameters existing in the field economies might not ever be provided to researchers in sufficient detail and accuracy to permit accurate predictions, even if the theory is right in principle.

Thus, the exercise reported here is devoted to an examination of relatively simple processes that have the essence of international finance. The questions posed are relative to the simple processes that we created for the purpose of the study and we make no particular claims about how the results here can be carried over to field applications. It might be said, however, that by experimental standards the economies that are studied are extremely complex. We doubt, seriously, that any body of theory from any other branch of science could presume to predict what might happen.

2. THE LABORATORY ECONOMIES

The experimental setup is consistent with requiring a type of cash-in-advance constraint, similar to that imposed by Lucas (1982). The parameters are set so that gains from exchange exist from purchasing in a foreign country. That is in the competitive equilibrium, foreign trade exists. However, the experimental environment requires that importers purchase foreign exchange in advance of their foreign goods purchase. Agents are also unable to sell goods in a foreign country in order to acquire foreign exchange. Therefore, agents must acquire foreign exchange in advance of their purchases of foreign goods.

Two countries were indexed A and B. Each country produced two goods that were called x and y. Each country had 3 buyers of x and y who were indifferent between the source of supply. That is, a consumer in A received the same utility from x supplied in A, or x supplied in B, and similarly with y. Consequently, it will make sense to talk about a demand and supply of x at either the country level or at the world level. In addition, each country had three suppliers, each of whom supplied both x and y.

Buyers in each country had utility functions of the form U.S. dollars = [a(M_C- M_O + R(x,y))], where a is a scale factor, M_C is the currency of the country in which the agent resides, M_O is the initial endowment of the home currency, and x and y are the consumption by the individual, measured in the units of the two commodities, and R is in terms of home currency. Similarly, suppliers in a given country have an incentive function of the form U.S. dollars = [b(M_C- M_O - $C_x(x)$ - $C_y(y)$)]. Notice that individuals place no value on the currency of the country in which they do not reside. So, this world has two countries with six agents in each, two commodities, and two currencies which have a value only to the agents of the home country.

Preferences are induced such that the aggregate demand and supplies are approximated by the equations that follow:

Country A

x demand: $43 - .75x - p^A_x = 0$ x supply: $2 + 2x - p^A_x = 0$

y demand: $65 - 3y - p^A_y = 0$ y supply : $11 + 1.5y - p^A_y = 0$

Country B

x demand: $925 - 45x - p^B_x = 0$ x supply: $127.5 + 15x - p^B_x = 0$

y demand: $2646 - 36y - p^B_y = 0$ y supply: $150 + 180y - p^B_y = 0$

The notation p^i_k means the price of commodity k that exists in country i. These functions are shown in Figure 1.

Constraints on trade were imposed to force the use of the international financial markets. First, all purchases and sales in a country had to be in terms of the home currency. It was not possible to buy in a foreign country without having foreign currency first. Second, no agent was allowed to export but all agents could import. This meant that an agent that wanted to buy foreign could not sell foreign in order to get the exchange. The agent was required to go to the exchange market and purchase foreign currency with the home currency. Once purchases were made abroad, they could be imported without cost and either consumed or resold for home currency.

3. EXPERIMENTAL DESIGN AND PROCEDURES

Four experiments were conducted. The subjects were students at the California Institute of Technology and the University of Amsterdam. Three sessions took place at the Laboratory for Experimental Economics and Political Science at Caltech, in California, and one took place at the Center for Research in Experimental Economics and Political Decision-Making (CREED), at the University of Amsterdam, Amsterdam, the Netherlands. A list of the experiments indexed by the date of the experiment can be found in Table 1.

The experiments were conducted in English and the subjects were paid in U.S. dollars at Caltech and in Dutch guilders at Amsterdam. All of the Amsterdam subjects had participated in one pilot experiment of this series previously. This was intended to acquaint them with the accounting procedures, the computer keys, and the general setting in which the economic activity takes place in an experiment. The Caltech subjects had not participated in international finance experiments previously, but a substantial fraction of the Caltech subjects had been in other market experiments before.

At the beginning of each experimental session subjects went through an interactive computerized instructional program which took about 30 minutes. This program gave them instructions about the keys and the other functions of the computer.[2] The experimenter read the instructions aloud, as the subjects followed along, reading from their own copy. The instructions are contained in Appendix A. Subjects were shown at the board an example of how to read a redemption value sheet and a cost schedule. They were also instructed on how to calculate their profits, which they were required to do on their end of period summary sheets. Examples of all of the written materials used can also be found in Appendix A.

After the instruction was completed, the market was replicated 11 times, each replication constituting a period. Each was like a trading day and each day was identical. The first period was for practice and did not count toward subjects' cash earnings. Each individual kept the same "utility function" in each replication, although individuals' utility functions differed among agents. Thus, the market environment was kept constant over the 10 periods following the practice periods. All inventories of goods and currencies were reset at the same starting level each 2 period. Nothing was carried over from period to period, except the earnings of the subjects.

In each of the experiments there were 12 subjects, 6 buyers and 6 sellers. There were 3 buyers and 3 sellers in each country. As a resident of a country, each agent was endowed with an inventory of his home currency, and only the home currency had value to him/her. Consumption and home currency cash had value in U.S. dollars, or Dutch guilders, depending upon the location of the experiment. Thus, subjects had placed no value on foreign currency, except as a means to the end of buying the goods abroad which could then be consumed or sold for home currency.

The market mechanism employed was a modified version of the computerized Multiple Unit Double Auction. The program was modified to allow for multiple countries, represented by different pages on the computer screen. Each page (country) contained three markets in which all trades took place in terms of the

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[2]This program is part of the general MUDA program outlined in Plott (1991) and is contained in the diskette which accompanies the general market program used in the experiment.

home currency. The page also listed that country's cash that the subject had on hand, which could be used to buy in the market in that country. Sales in that country added to that country's cash that the subject had on hand. The three markets allowed trading of x, y, and the currency of the other country. So purchases and sales in these markets, as well as the purchase and sale of the currency of the other country, were made in terms of the currency relevant to the page and all bids and asks were quoted in terms of the currency of that page. When the subject changed pages to the other country, the cash on hand of the first became the inventory of currency on the second page, and the inventory of foreign currency on the first page became the cash on hand on the second page. This convention automatically enforced the requirement that all transactions in a country took place in terms of the currency of that country.

Any agent could import from another country but no individual could export directly. The MUDA program allows for transformations of inventory in one group of markets (one country) to another group of markets (another country). This feature was used to implement imports. Purchases in a foreign country, made with the currency from that country, were automatically credited to the inventory of the commodity held by the subject in the foreign country. The inventory of that commodity could be costlessly transformed into the inventory of the same commodity in the subject's home country. Once in the home country, the commodity could be sold at home for cash or consumed. Thus, imports were allowed but exports were not allowed. That is, no individual could transform inventories held at home to the inventory of the same commodity held in the foreign country. This restriction was needed to force the use of the currency markets. If both imports and exports had been allowed, the subject could have exported a commodity and sold it for foreign currency, which could have then been used to purchase commodities for import and sale at home without ever using the foreign currency markets. Since the operation of the currency market was considered to be a fundamental purpose of the experiment, steps were taken to make sure that such markets had a function and would thus be used.

4. MODELS

Two models are considered, competition and autarky. In the competitive model, agents make trades of commodities and corresponding purchases and sales of foreign exchange to permit these trades. There is no role for money, foreign or domestic, other than this transactions demand. Since the experimental agents receive payoffs for domestic (but not foreign) currency held at the end of each period, this is an economy in which demanders and suppliers have (domestic) money in their utility functions. In other words, the domestic money has commodity value but not to foreigners.

The competitive outcome can be found by solving equations 1-7. There is also a possibility that autarky will occur. That is, traders will choose not to engage in foreign trade. This is not an unreasonable notion, as one might believe at first glance, considering the risk of the foreign exchange market and the complexity of international transactions.

THE COMPETITIVE MODEL

The competitive model has three components. Home market demand and supply give four equations which require material balance and that incentives to buy and sell be equated at existing prices. The second set of equations, which we call purchasing power parity, can be viewed as common arbitrage conditions. They require that prices in the two countries, adjusted for exchange rates, be the same. The final component requires equilibrium in the foreign exchange market, given the special definitions of market demand and market supply based on imports and exports. Of course, these three components can be viewed as partial equilibrium models independently of any general equilibrium implications.

home market demand and supply

The law of supply and demand in the home markets captures the idea that home prices are determined by local demand, plus exports in relation to local supply, plus imports. In essence, the principles of demand and supply operate

independently of the ultimate destination or use of the commodities. The theory is captured by the following equations.

(1) $D_x^A(p_x^A) + \text{Imports} = S_x^A(p_x^A)$ (2) $D_y^A(p_y^A) = S_y^A(p_y^A) + \text{exports}$

(3) $D_x^B(p_x^B) = S_x^B(p_x^B) + \text{Exports}$ (4) $D_y^B(p_y^B) + \text{Imports} = S_y^B(p_y^B)$.

purchasing power parity

In contrast to the home market demand and supply, the purchasing power parity theory generalizes the idea of market clearing to extend across international boundaries. In the absence of tariffs, taxes, transportation costs, and other complicating factors, the theory asserts that the prices of the goods will be the same in all countries after prices are factored by the exchange rates. It is the purchasing power parity theory which can be interpreted as governing the flow of imports and exports in response to relative prices and the exchange rate.

Let r be the exchange rate, that is, the price of currency A in terms of currency B. The equations for the purchasing power parity theory are:

(5) $r\,p^A_x = p^B_x$ (6) $r\,p^A_y = p^B_y$.

flow of funds theory

It is the flow of funds theory that provides the final equation for exchange rate determination. Briefly, the theory is another way of saying that the exchange rate is determined by the demand and supply of a currency. Formally the equation is:

(7) (Demand for imports of x in A) p^B_x = r (Demand for imports of y in B) p^A_y.

The left hand side of the equation is the international demand for currency B that results from the country A purchases of x from country B. Country A needs this amount of the currency in order to make the purchases. The right hand side of the

equation is the supply of currency B in the international market. The imports of y by country B, when multiplied by country A price of y, yields the total amount of country A currency that is needed by country B in order to purchase the imports. When multiplied by the exchange rate (the units of currency B needed to purchase a unit of currency A), the quantity on the right hand side of the equation becomes the international supply of currency B.

Care must be exercised in interpreting these last equations. First, prices have an inverse measurement. Suppose the demand for currency B is greater than the supply. The price of currency B should go up, at least according to the law of supply and demand. But, that is a decrease in the exchange rate r because r is measured in units of B per unit of A, so an increase in the price of B is a decrease in r. Secondly, unless operational definitions are selected carefully, equation (7) can acquire the properties of a tautology. In particular, if "actual imports" are substituted for the "demand for imports," and if all international exchange is spent on foreign goods (no unused exchange and no currency speculation), and if r is defined as an appropriate weighted average of transactions, then the equation must be satisfied by virtue of the definitions. In the analysis that follows, actual imports are used in the statistical analysis so the degree to which the equation is not satisfied reflects the existence of speculation, wasted exchange and the lack of appropriate weighting of individual transactions in the determination of the measure of r.

AUTARKY MODEL

The autarky model is one alternative to the competitive model. It predicts that international trade will not take place and, instead, the economies will operate as if they were in isolation. In many respects, the model should be taken seriously and not only as a benchmark. If the currency markets suffer from continuous disequilibrium, if the dynamics of adjustment are such that international trade is hazardous, or if the transactions are too slow/fast, then trade might not take place.

5. PREDICTIONS

The models predict the exact value of each of the variables in the system. That is, the models predict the prices in all countries and all commodities, the exchange rate, the magnitude of imports and exports, etc. These predictions are summarized in Table 2.

The prediction of the competitive model is the solution to equations (1) through (7). The prediction of the autarky model is the solution of equations (1) through (4) with the value of all imports and exports constrained to be zero. The table displays the solutions to the equations rounded to the nearest integer. The exact demand and supply functions used in the experiment were discrete step functions that are approximated by the continuous functions used here. They are contained in Appendix B..

6. STATISTICAL METHODOLOGY

The application of statistical models to experimental market data is characterized by some classic problems. This section will facilitate an understanding of what we did and the possible limitations imposed by our methodology. Two problems appear to be without any good solution, given the current state of theory and techniques, so all conclusions must be evaluated in light of the tentative assumptions that are explicit and implicit in the statistical models. The first problem is that the models, like the competitive model, make predictions of the magnitudes of a large number of variables. From an intuitive point of view it is not surprising if the model fails on one or even several dimensions, but the statistical model that we have available is not forgiving of errors of any type. The second problem occurs because the economic model is a static equilibrium model, while the data are clearly generated by a dynamic process. Furthermore, in simpler experiments the existence of a convergence phenomenon has been demonstrated on many occasions. Thus, any statistical model must be sufficiently forgiving of the lack of theory to allow some latitude for convergence.

The first problem is not addressed. Instead, each of the major predictions of a model is considered separately. Each variable is observed separately and the

question is posed about its magnitude in relation to the predictions of one or the other of the models.

The second problem is addressed by the application of a simple dynamic model. This model assumes that for any particular dependent variable, each experiment may start from a different origin but that all markets will experience adjustment, as described by a common functional form. Furthermore, the model assumes that the variable will converge to a common asymptote. Formally, the model is as follows:

$$(8)\quad z_{it} = B_{11}\, D_1\, (1/t) + \ldots + B_{1K}\, D_K\, (1/t) + B_2\, ((t-1)/t) + u$$

where i is the index of the experiment. D_j are dummy variables that take value 1 if i = j and value 0 otherwise. t is time measured in terms of experimental period number. K is the number of experiments. u is a random variable distributed normally with 0 mean.

Notice that the statistical model has some useful properties. It allows for the possibility that variables may take different values at the start of different experiments. The terms B_{1i} measure these different origins of the data for the different experiments. The model then captures the specification that the experiments are converging to a common asymptote. During the early periods the asymptote gets no weight because the term (t-1)/t is small but as t gets large the term goes to 1 while 1/t goes to 0. Thus, the weight of the end of the period data are on the common term B_2.

Thus the model can be used to test the hypothesis that the data are converging to the predictions of various models by testing whether or not the estimates of B_2 are near the predictions of the model. In addition, a notion of weak convergence can be used to assess the models. Comparison of the B_{1j} terms with the B_2 term reveals the direction of convergence. If the B_2 term is closer to the model's prediction than is the B_{ij} terms, we say that the data are weakly converging to the model's predictions.

7. RESULTS

Figures 2, 3 and 4 contain time series for experiment 042193. On the vertical axes are measured the prices in terms of the currency in which transactions took place. On the horizontal axes is measured the time in seconds when actions took place. Vertical lines indicate the start and end of periods. Each country had two commodity markets. These are combined as time series on a single figure. The data from country A are in Figure 2 and the data from country B are in Figure 3. One horizontal line represents the value of the competitive equilibrium for the appropriate variable and another indicates the prediction of the autarky model. Both lines are labeled accordingly. Figure 4 contains the time series for the exchange rate. The scale of prices in country B is so large that the exchange rate time series gets lost .

Estimates of the parameters of the statistical model are contained in Table 3. The standard errors are in parentheses. Each variable is estimated separately. In addition, separate tests are developed from the equations that define purchasing power parity theory and flow of funds theory. These tests are also contained in the table. The standard errors are corrected for heteroskedasticity using White's covariance matrix estimator.

The analysis begins with the most central variables, the exchange rate and the volume of exchange. If the response of these variables to the underlying economic conditions is not as predicted by theory, then the magnitudes of all other variables would be affected relative to theory. The first result is that the exchange rates are at a level anticipated by the competitive model. The second result is that the volume of exchange falls short of the competitive quantity.

RESULT 1. Exchange rates converge to the competitive prediction.

SUPPORT. The competitive equilibrium exchange rate is 47. The estimate of B_2 for the exchange rate variable is 47.127 with a standard error of 1.34. The hypothesis that the exchange rates are converging to the predictions of the competitive equilibrium model cannot be rejected.•

RESULT 2. The volume of exchange in the international market falls short of the competitive equilibrium volume. In only two of the experiments is the volume weakly converging to the competitive equilibrium. The autarky model can be rejected.

SUPPORT. The estimates from the model are in Table 3 listed as the variable <V cur> . The estimated asymptote of the volume is 386 compared with the competitive equilibrium volume which should be at least 480. It could be more than 480 without being inconsistent with the model because of the possible existence of speculation. The hypothesis that the actual equals the theoretical can be rejected. In addition the B_{1j} terms for the first two experiments are closer to the competitive equilibrium than the asymptote so weak convergence in these two cases is questionable.•

Result two serves as a signal that these systems are not exactly on track as described by the competitive equilibrium model. Since the volume is not accurate the simultaneous nature of the model's equation system suggests that inaccuracies are likely to exist elsewhere. The following results constitute an attempt to isolate the errors and an attempt to find the fundamental causes. The prices that exist in each country are the obvious places to begin. That beginning is addressed by the following result.

RESULT 3. Prices in countries do not converge to the competitive equilibria in the strong sense but they converge in the weak sense. In all cases prices are closer to the competitive equilibrium than to autarky.

SUPPORT. The table contains the estimates of the B_{1j} term for two countries, two commodities and four experiments. It contains the estimate of the B_2 terms for each of the four prices (two countries, two commodities). All are statistically different from the predictions of the competitive model. All are closer to the predictions of the competitive model than to the predictions of the autarky model. In all but four cases (three instances for p^A_y and one instance of p^B_y) of the sixteen possibilities, the data are further from the competitive equilibrium at the start of the experiment than at the end.•

It is interesting to note that while the absolute prices are not on the competitive equilibrium, the movements are in that direction. The next result asks if the price ratios in a country are as predicted by the model. Are the relative scarcities in a country being reflected by prices even though the absolute levels of prices are off? The answer, provided by the result, is that the price ratios in both countries are not at the competitive levels but the movement is in that direction.

RESULT 4. Relative prices of x and y are converging in the weak sense toward the competitive equilibrium prediction in both countries. The competitive equilibrium is a better predictor than is autarky.

SUPPORT. The table contains the test. As can be seen, the hypothesis that B_2 is the ratio that is predicted by the competitive equilibrium can be rejected in both cases (two countries and two price ratios). The ratios seem close to 0.7 and 0.3 as compared to the equilibrium condition of 0.4 and the differences are statistically significant. The weak convergence is clearly present since, in all but one of the eight possible cases, the data at the beginning of the experiment are further from the competitive equilibrium than are the pooled data at the end. In both cases the B_2 estimate is closer to the competitive equilibrium than it is to the autarky predictions•

The previous result examined the data from the point of view of relative prices within a country. The next result views the data from the perspective of relative prices across countries and factors in the exchange rate. It indicates that the nature of the responses of the variables to the underlying economic conditions might differ according to the commodity.

RESULT 5. Purchasing power parity, as defined by equations (5) and (6), receives some support in one of the markets (the y) but is rejected in the other (the x). Weak convergence is not present in the x market, but is present in the y market.

SUPPORT. The test statistics are in the table. The hypothesis that the equation is satisfied in the y market can be rejected at the .05 level which, in this context, is

interpreted as borderline. The coefficient is 1.1, as opposed to the 1.0 predicted by the competitive model. Weak convergence is also present in every experiment. In the x market the coefficient is 0.5 as opposed to 1. This means that the values are off by about 50%. In the x market only one of the experiments is closer at the end than it was at the beginning ; but, in three of the four cases, the B_{1j}'s are not significantly different from the point estimate of B_2.•

The previous two results suggest that inaccuracies of the competitive model reside in both intercountry comparisons and intracountry comparisons. The next result is an attempt to focus more clearly on the behavior of the localities where the price formation process takes place. Equations (1) through (4) are local market demand and supply equations. These say that, in each country and for each commodity, the local prices are set by the local conditions of demand and supply, together with the imports and exports. They are statements about the reaction of domestic economies to the underlying economic forces. The question posed is whether or not excess demand, as defined by the actual parameters of the experiment and by the observed prices, exists in the local economies. Have the prices adjusted in the domestic economies, or are they adjusting to satisfy the partial equilibrium conditions that demand equals supply? The result suggest that the two countries are adjusting much differently.

RESULT 6. The hypothesis that domestic excess demand is converging to zero can be rejected in country A for good x. Domestic excess demand is converging to zero in country B, for both goods, and for y in country A in the weak sense.

SUPPORT. Excess demand is defined by actual experimental parameters. Prices are average prices in a period. The estimated coefficients in Table 3 provide the support. In country A there is an excess supply of x at the asymptote of the adjustment path of 9.6 units. This is significantly different from zero. Furthermore, the asymptote is further from the equilibrium than the starting point in three of the four experiments. Similarly there is a significant excess demand (3.6 units) for y in country A. However, the quantity is small and this market is converging in the weak sense to an excess demand of zero in three of the four experiments, and the fourth experiment show no statistically significant movement. In country B the x market provides weak support for the hypothesis of

zero excess demand and the excess demand is converging to zero in the weak sense in three of the four possible cases. In country B the excess demand for y is converging to zero.•

The above result indicates that the law of supply and demand is operating at the local levels but an inexplicable asymmetry exists between the countries. The question to pose is whether there might exist a deeper problem due to the way that the law is formulated at the international level to determine the exchange rate. The next result is fundamental. It says that the flow of funds theory is operating to determine the rate of exchange.

Figure 5 contains a time series of the demand and supply of international exchange, as predicted by the flow of funds model. The demand for foreign exchange by country A, is defined to be the country's actual imports from country B, times the price of the good in country B. The supply of foreign exchange is the actual imports of country B, times the country A price of the good that B is importing, times the exchange rate. The two time series are labeled and graphed for each of the four experiments. The visual impression is that the quantity of exchange demanded is converging to the quantity of exchange supplied. The next result makes that visual impression precise.

RESULT 7. Flow of funds theory as represented by equation (7) where the demand for imports is represented by actual imports, is supported in the data.

SUPPORT. The variable $(IMP^{A}_{x})(p^{B}_{x}) - (r)(IMP^{B}_{y})(p^{A}_{y})$ was measured with the standard model. The estimates in Table 3 show that the time series is converging to 0 which is the prediction of the competitive model. The B_2 term is measured to be 1251 which is not significantly different from 0.•

The above results suggest that the patterns of international finance are similar but not exactly as predicted by the competitive model. For the most part the financial variables are moving in directions that would be suggested by the competitive equilibrium model. Either wasted exchange or speculation occurs at first, but decreases over time. The next series of questions inquires about the real sectors of the economies and the underlying trade. Since the financial variables are moving in ways that the competitive model anticipates, it might be expected that the real

sectors are responding accordingly also. The next result says that the patterns of specialization are consistent with competitive theory.

RESULT 8. International trade patterns are consistent with the principle of comparative advantage.

SUPPORT. The competitive model predicts that country A will import x and country B will import y. As shown in the table, net imports of x by country A are 24.5 units and net imports of y by country B are 8.8 units. These levels are short of the quantitative predictions of the competitive model of 32 units and 12 units respectively, however, in all but one of the eight possible cases, the direction of movement is toward the competitive equilibrium quantities. These patterns are sufficient to support the result.•

Since trade is developing along the lines of comparative advantage and since the financial sectors are not far out of line, both consumption and production patterns should be conforming to the model. Since such conformity need not be the case, except as dictated by the principles of economics, which are under investigation, it is necessary to check. The next two results indicate that both are moving in the directions anticipated.

RESULT 9. Consumption patterns are moving toward the predictions of the competitive model.

SUPPORT. Two countries and two commodities represent four variables to consider. All four of these variables are significantly different from the competitive equilibrium as measured by the B_2 term. But, in a sense, are very close. For example, there are 8.69 units of consumption of y in country A (the competitive equilibrium is 8 units) and 6.04 units of consumption of x in country B (the competitive equilibrium is 5 units). However, the variables are weakly converging in all but two of the sixteen possible cases (as measured by the B_{1j} estimates as opposed to the B_2 estimates).•

RESULT 10. Production patterns are moving toward the predictions of the competitive equilibrium model.

SUPPORT. In four of the 16 cases (4 variables and 4 experiments) the production levels are weakly converging to the competitive equilibrium.•

8. CONCLUSIONS

The autarky model can be solidly rejected by these experiments. It is not the case that the hazards of the foreign exchange markets as such that international trade stops or takes place at very low levels only. On the other hand, the competitive model is not perfect. Although, in most instances, the outcome variables are converging to the competitive prediction in the weak sense, the model fails to predict the exact levels of activity in many instances, even when the asymptotic tendencies are incorporated. Hazards of trade do exist and can appear in the form of "wasted" exchange. However, the equilibrating tendencies of the system serve to reduce the uncertainty and facilitate trade.

Generally speaking, the exchange rate seeks a level that is near that predicted by the competitive model. It converges from below and seems to be driven by the flow of funds model of exchange rate determination. However, that creates somewhat of a paradox. International trade is below competitive levels. This relatively low level of international trade may be associated with the relative prices lying between the competitive and autarky predictions in both countries. Country A seems to be more problematic with the price of x persistently much higher than the competitive equilibrium level. The price of x in A explains the strong rejection of purchasing power parity for x.

In general, prices within countries do not seem to be adjusting rapidly to local demand and supply conditions, although there is evidence of slow convergence to local market clearing. The adjustment is not taking place at all for market x in country A.

Despite the behavior of local and international price ratios, the real sectors of the economies are moving in the directions of the competitive equilibrium. Patterns

of international trade are consistent with the law of comparative advantage. Local production and consumption levels are converging to the competitive equilibrium as well.

The competitive model is not perfect, in any sense, but the principles on which the general theory is based, leads to a model that predicts the general movement of economic activity in a very complex and interdependent setting. When people discuss vague concepts of "economic forces," these data suggest that the formalization of the concepts with the competitive equilibrium model can be very useful. The forces are increasing the international trade between the two countries, with the result that the magnitudes of most outcome variables, especially net exports, production, consumption, and the exchange rate, move slowly toward the competitive equilibrium.

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Lucas, Robert E., "Interest Rates and Currency Prices in a Two-Country World," *Journal of Monetary Economics*, 10 (1982): 335-359.

Plott, Charles R., "A Computerized Laboratory Market System and Research Support Systems for the Multiple Unit Double Auction," Social Science Working Paper no. 783, California Institute of Technology, Pasadena, November 1991.

TABLE 1: EXPERIMENTS: LOCATION, SUBJECTS, EXPERIENCE

INDEX	LOCATION	NUMBER OF SUBJECTS	EXPERIENCE	NUMBER OF PERIODS
011393	Caltech	12	general market	10
011493	Caltech	12	general market	10
040793	University of Amsterdam	12	1 pilot experiment	10
042193	Caltech	12	general market	10

TABLE 2: PREDICTED PRICES OF THE COMPETITIVE EQUILIBRIUM MODEL AND THE AUTARKY MODEL: COUNTRIES A AND B; COMMODITIES X AND Y; AND EXCHANGE RATES OF CURRENCIES A AND B

PRICES

	country A x	country A y	country A crA/crB	country B x	country B y	country B crB/crA
Comp. Eq.	15	41	1/47	682	1888	47
Autarky	32	29	.....	327	2230	.....

Prices in the table are the values of the solution to the continuous approximation of the experimental parameters rounded to the nearest integer.

TABLE 3: ESTIMATES OF STATISTICAL MODEL; COEFFICIENT ESTIMATES (STANDARD ERRORS); HYPOTHESIS TESTS AND GENERAL STATISTICS

Var.	B_{11}	B_{12}	B_{13}	B_{14}	B_2	R^2	DW	CE Pred.	Aut. Pred.	CE Rej.	Aut. Rej.
r	27.393	-1.249	24.582	30.551	47.127	.65	1.15	47	-	No	-
	(5.002)	(6.384)	(1.906)	(3.304)	(1.340)						
px^A/py^A	0.769	1.174	1.034	0.858	0.706	.43	.87	.4	1.156	p<.005	p<.005
	(0.043)	(0.081)	(0.089)	(0.053)	(0.026)						
px^B/py^B	0.230	0.482	0.279	0.312	0.330	.25	1.83	.4	.144	p<.005	p<.005
	(0.035)	(0.042)	(0.083)	(0.023)	(0.015)						
$px^B/r.px^A$	0.639	1.693	0.736	0.541	0.531	.56	1.90	1	-	p<.005	-
	(0.087)	(0.270)	(0.231)	(0.076)	(0.040)						
$py^B/r.py^A$	1.969	4.144	2.420	1.447	1.101	.74	2.02	1	-	p<.05	-
	(0.269)	(0.525)	(0.076)	(0.153)	(0.058)						
IMP_A^X	3.356	-25.982	14.102	2.138	24.526	.72	1.27	32	0	p<.005	p<.005
	(3.472)	(8.606)	(3.964)	(3.166)	(1.245)						
IMP_B^Y	1.537	11.231	8.601	4.349	8.863	.14	2.24	12	0	p<.005	p<.005
	(2.541)	(4.199)	(3.555)	(1.814)	(0.749)						
xac	15.960	-0.064	23.078	16.289	32.002	.71	1.20	38	14	p<.005	p<.005
	(1.878)	(6.069)	(3.774)	(1.598)	(0.889)						
yac	11.673	7.880	10.774	13.069	8.694	.21	2.48	8	12	p<.025	p<.005
	(0.590)	(1.594)	(1.025)	(0.551)	(0.352)						
xbc	14.809	21.825	11.881	15.368	6.042	.73	1.54	5	13	p<.005	p<.005
	(1.328)	(1.601)	(0.734)	(1.170)	(0.380)						
ybc	15.075	15.593	20.070	15.212	18.945	.08	2.17	21	12	p<.005	p<.005
	(2.687)	(2.898)	(3.162)	(1.942)	(0.639)						
xap	12.498	24.435	9.514	14.044	7.595	.51	1.52	6	14	p<.005	p<.005
	(1.871)	(2.777)	(1.018)	(2.097)	(0.571)						
yap	13.070	18.963	19.298	17.277	17.715	.11	2.01	19	12	p<.01	p<.005
	(2.151)	(2.558)	(2.522)	(1.502)	(0.505)						
xbp	18.216	-2.729	26.035	17.588	30.510	.57	1.17	37	13	p<.005	p<.005
	(2.250)	(8.051)	(4.595)	(2.361)	(1.201)						
ybp	13.933	4.263	11.585	11.043	9.879	.63	2.68	10	12	No	p<.005
	(0.355)	(1.061)	(0.382)	(0.341)	(0.213)						
V cur	401.61	528.28	70.75	65.61	386.01	.25	2.028	≥480	0	p<.005	p<.005
	(178.75)	(125.49)	(107.36)	(49.167)	(29.458)						

Definitions:

xac = x consumed in country A.
xap = x produced in country A
V cur = volume in currency market (currency A)
FF = flow of funds
IMP_A^X = imports of x into country A

The order of the variables in the table corresponds to the order of results. Variables relevant to result 1 first, etc.

TABLE 3 (cont.): LOCAL MARKET CLEARING

Variable	B_{11}	B_{12}	B_{13}	B_{14}	B_2	CE = Aut. pred.	DW	R^2	CE. Aut. Rejected
$Dx^A(px^A) - imp_x^A - S_x^A(p)$	-3.107 (2.935)	4.022 (4.102)	-18.729 (8.155)	-8.248 (4.906)	-9.646 (1.555)	0	1.139	0.15	p<.005
$Dy^A(py^A) + imp_y^B - S_y^A(p)$	-10.526 (4.692)	2.934 (3.786)	4.984 (4.458)	-7.081 (2.739)	3.690 (1.017)	0	1.366	0.24	p<.005
$Dx^B(px^B) + imp_x^A - S_x^B(p)$	-15.242 (2.972)	-31.775 (9.056)	-3.402 (18.382)	-12.699 (3.448)	-4.895 (2.767)	0	1.580	.07	p<.05
$Dy^B(py^B) - imp_y^B - Sy^B(p)$	-3.523 (-1.008)	42.373 (4.658)	2.872 (1.141)	16.468 (3.130)	-1.189 (1.250)	0	1.755	.58	not rejected

Figure 1

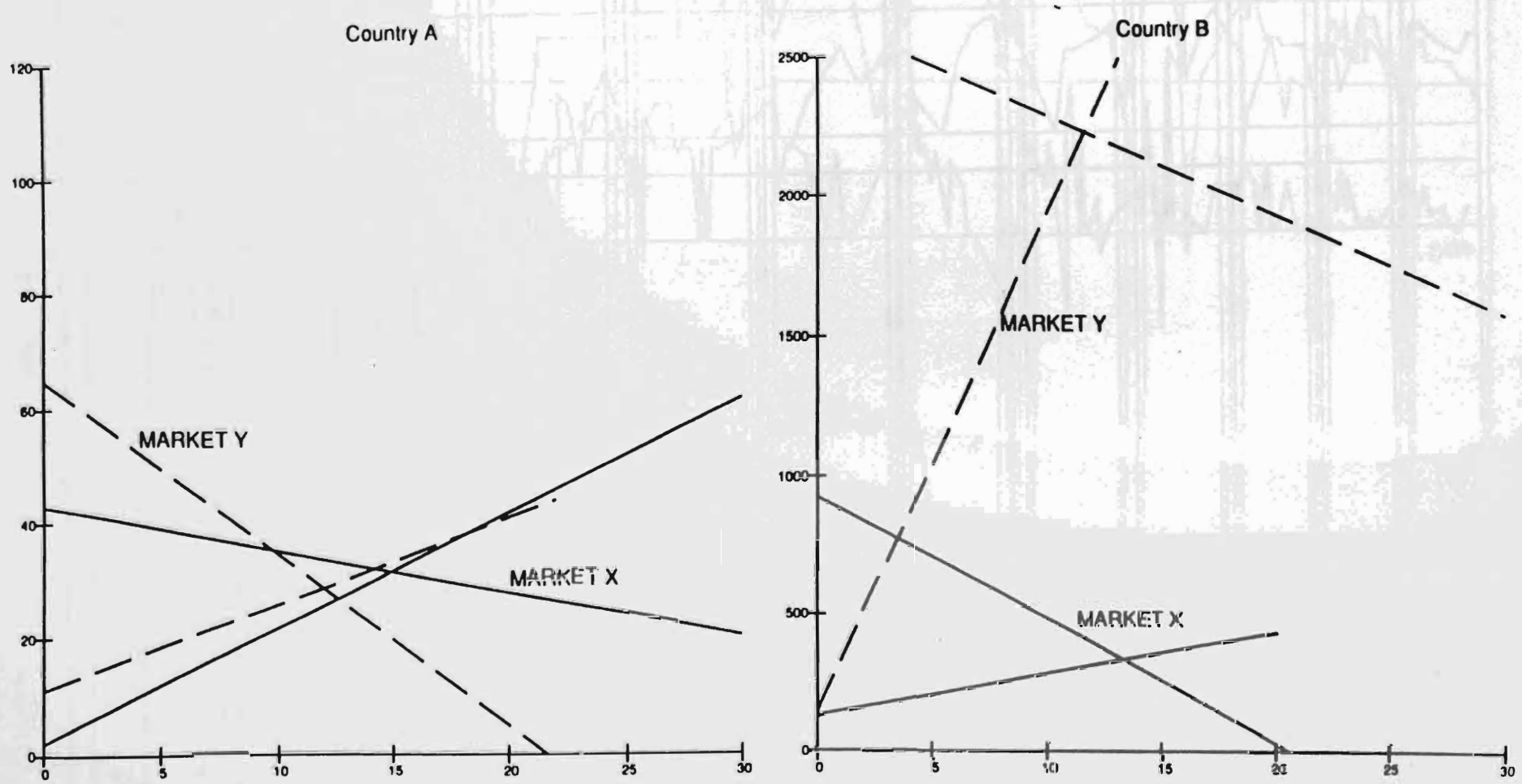

Country A
120
100
80
60
40
20
0
MARKET Y
MARKET X
0
5
10
15
20
25
30
Country B
2500
2000
1500
1000
500
0
MARKET Y
MARKET X
0
5
10
15
20
25
30

Figure 2 - Country A

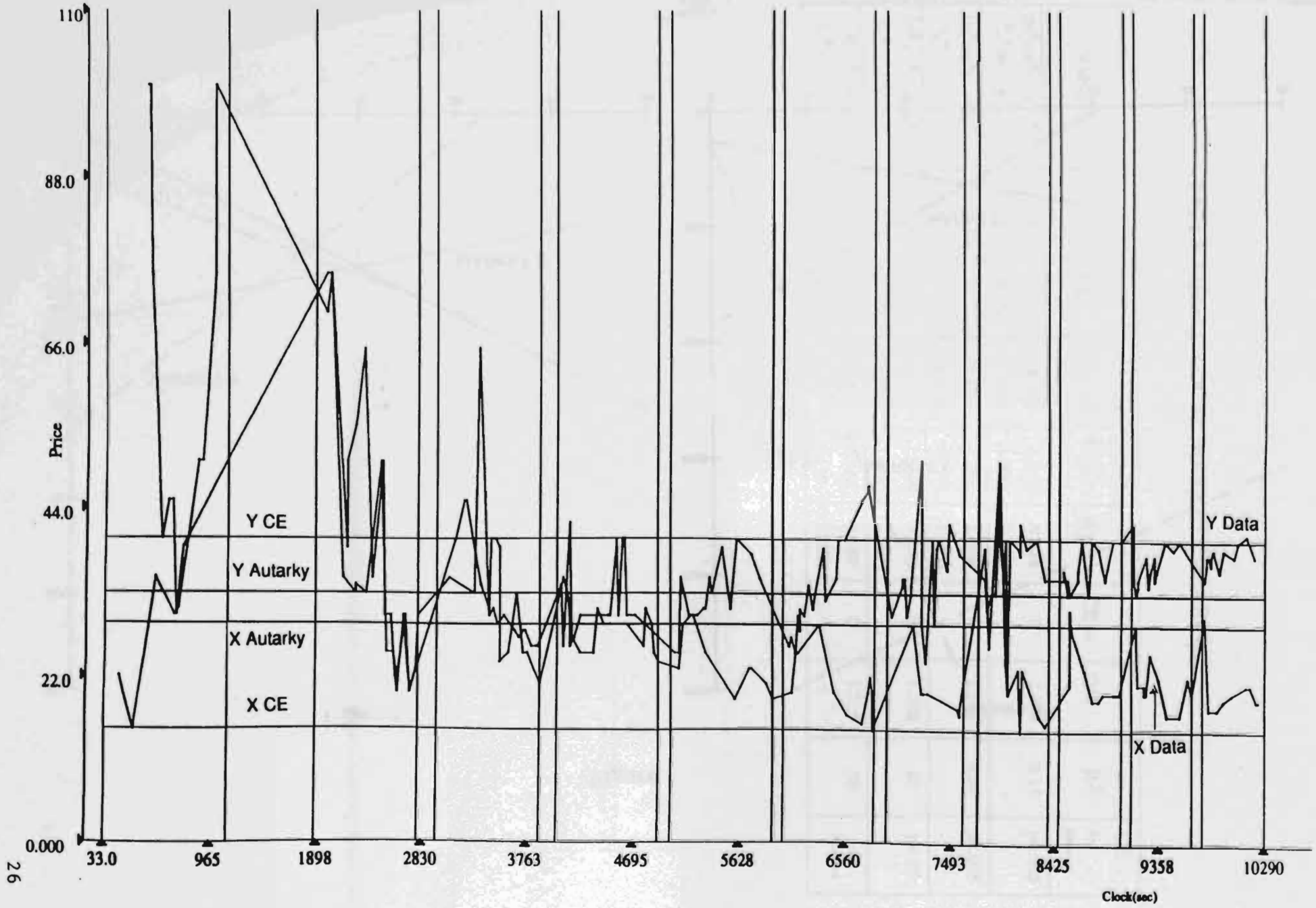


Figure 3 - Country B

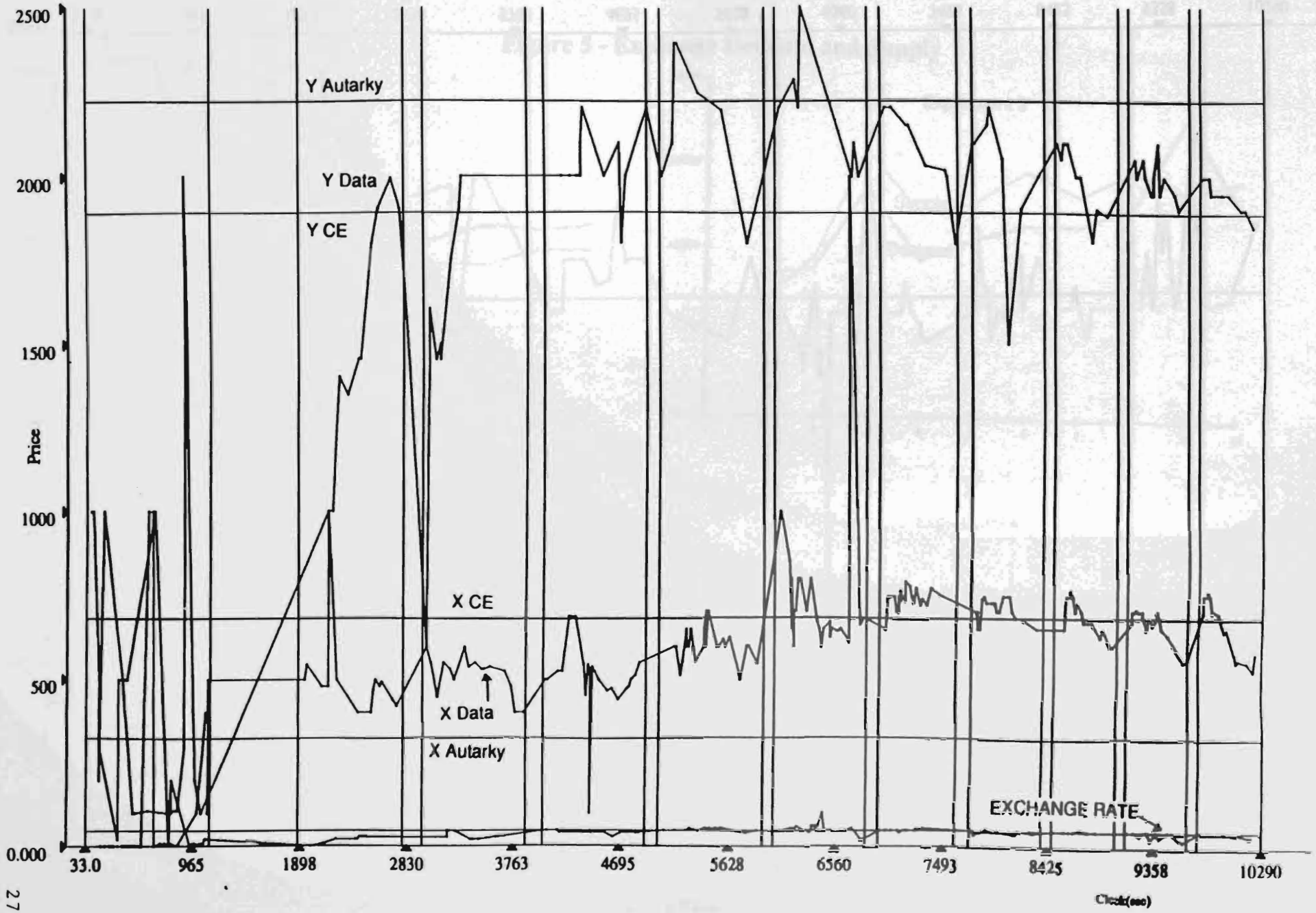


Figure 4 - Exchange Rates

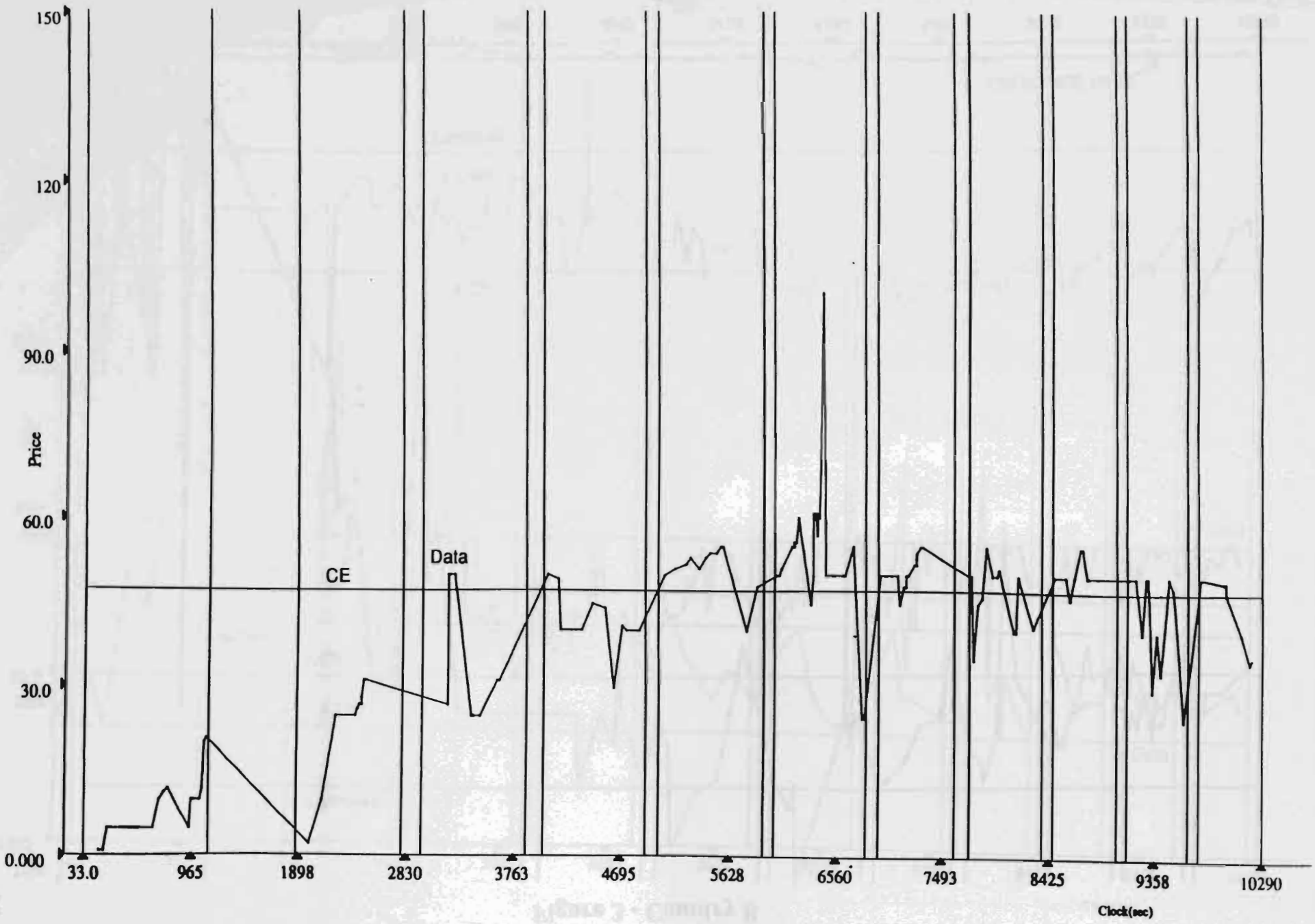
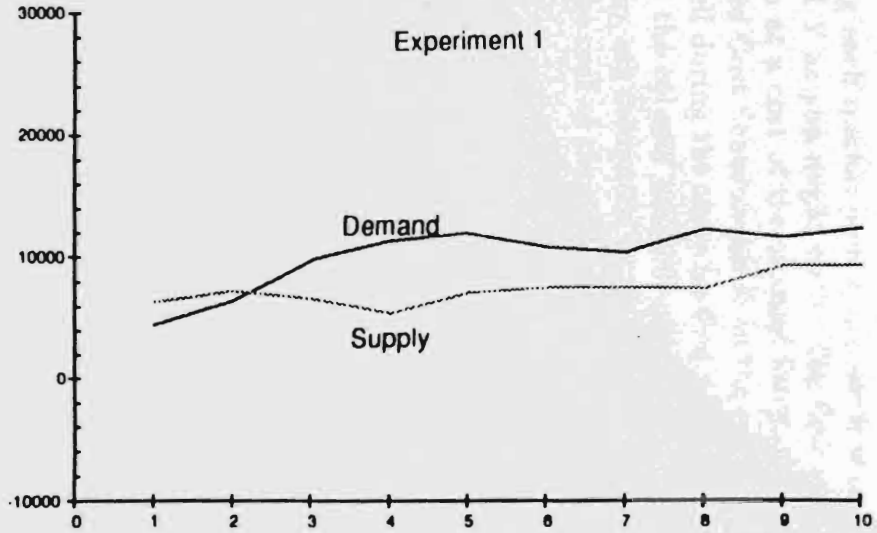
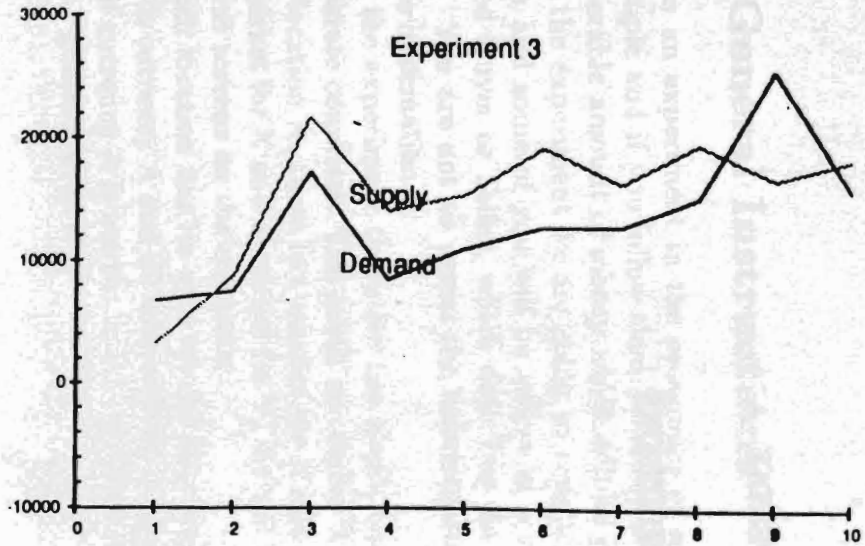
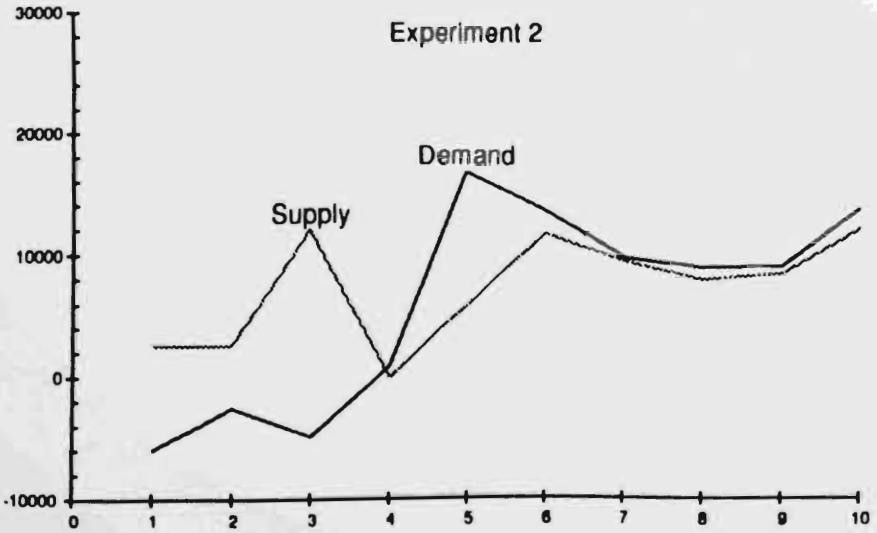
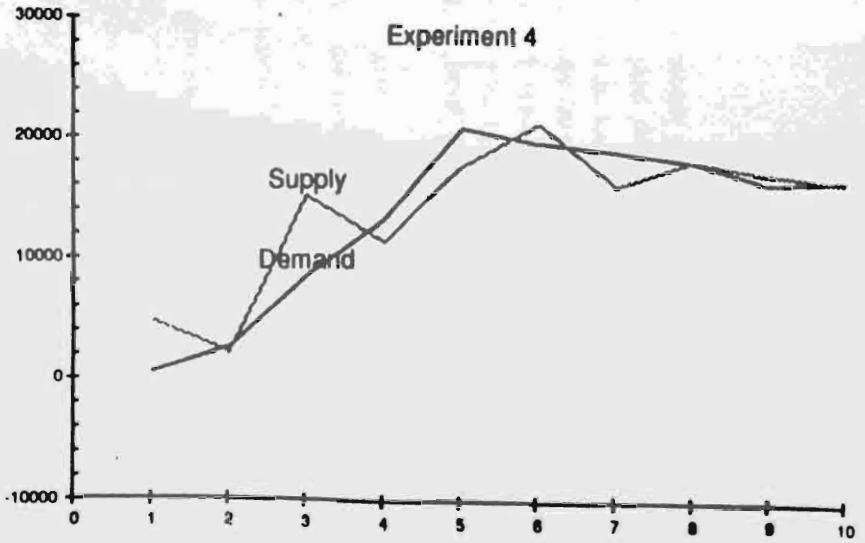


Figure 5 - Exchange Demand and Supply









APPENDIX A

INSTRUCTIONS

1 General Instructions

This is an experiment in the economics of market decision making. The instructions are simple and if you follow them carefully and make good decisions, you might earn a considerable amount of money which will be paid to you in cash.

In the experiment we are going to conduct an market in which some of you will be buyers and some of you will be sellers in a sequence of trading periods. Find a sheet labelled Buyer or Seller, which describes the value to you of any decisions you might make. You are not to reveal the information on this sheet to anyone. It is your own private information.

In the experiment there are two goods and two locations, which you could think of as separate countries. The goods are called X and Y and the locations are called A and B. In location A, there is a market for X and a market for Y. Also, in location B, there is a market for X and a market for Y. As will be explained later, the locations will be on different screens on the computer.

Each location has its own special currency. All transactions in location A will take place in currency A and all transactions in location B will take place in currency B. Each unit of currency A is worth ..... guilders to you and each unit of currency B is worth ..... guilders to you.

2 Specific Instructions to Sellers

During each market period you are free to sell to any buyer or buyers as many units of X and Y as you might want. The first unit of X that you sell in a trading period, you obtain at a cost of the amount listed on the sheet in row (1) in the section of the sheet entitled Cost Schedule for X, in the column labelled unit cost. The second unit of X that you sell during the same trading period you obtain at a cost of the amount listed in row (2) in the column marked unit cost, etc... The profits from each sale, which are yours to keep, are computed by taking the difference between price at which you sold the unit and the cost of the unit. That is:

Your Earnings = Sale Price of Unit - Cost of Unit

Suppose, for example, that you sell two units of X and that the cost for the first unit of X is 140 and for the second unit is 160. If you sell the first unit at 200 and the second at 190, your earnings are:

Earnings from First = 200 - 140 = 60

Earnings from Second = 190 - 160 = 30

Total Earnings = 60 + 30 = 90

The end of period summary will help you record your profits. On row A, record the total cost of X that you sold during the period. The X which you sold during the period is equal to your inventory of X at the beginning of the market period minus your inventory at the end of the market period. This total can be found in the row of the section labelled Cost Schedule for X corresponding to the amount of X you sold during the period in the last column, which is entitled total cost. For example, if you sold two units during the market period, the total cost can be found in row (2). Similarly, on row B, record the total cost of Y that you sold during the period.

On rows (C) and (D) record your beginning of period and end of period inventory of the currency which has value to you. On row (E), enter an amount equal to the amount in row (D) minus the amount in row (C). (E) indicates your net change in cash for the market period. On row (F) record your total profit for the period. The total profit equals the total cash obtained from sales of X and Y minus the cost of the X and Y sold. It also equals the amount in row (E) minus the amount in row (A) minus the amount in row (B). Subsequent periods should be recorded similarily.

3 Specific Instructions to Buyers

During each market period, you are free to purchase from any seller or sellers as many units of X and Y as you might want. For the first unit of X that you buy in a trading period, you will receive the amount listed in row (1) in the section of the page entitled redemption value schedule for X in the column marked unit value. If you buy a second unit during the trading period, you will receive the additional amount listed in row (2) in the column marked unit redemption value, etc... The profits from each purchase, which are yours to keep, are computed by taking the difference between the redemption value and the purchase price of the unit bought. That is:

Your Earnings = Redemption Value - Purchase Price

Suppose, for example, that you buy two units and that your redemption value for the first unit is 200 and for the second unit is 180. If you pay 150 for the first unit and 160 for the second unit, your earnings are:

Earnings from First = 200 - 150 = 50
Earnings from Second = 180 - 160 = 20
Total Earnings = 50 + 20 = 70

The end of period summary will help you record your profits. In row (A) enter the total value of X consumed. This amount can be found in the column labelled total value

in the row corresponding to the total number of X held in your inventory at the end of the period. Similarily, record the total value of Y consumed in row (B).

On rows (C) and (D) record your beginning of period and end of period inventory of the currency which has value to you. On line (E), enter an amount equal to the amount in row (D) minus the amount in row (C). On line (F) record your total profit for the period which equals your redemption values for having X and Y in your inventory at the end of the market period, minus the cash which you spent to acquire them.

4 Currency

The locations are indicated by two computer screens. You can move from screen to screen by using the page up and page down keys. On each screen Cash on Hand is given in the upper right corner. On one screen, which represents location A, the Cash on Hand indicates your inventory of currency A. On the other screen, which represents location B, the Cash on Hand indicates your inventory of currency B.

While at location A, market 3 allows you to buy and sell currency B. Similarily, while at location B, market 6 allows you to buy and sell currency A.

All participants may transfer units of X and Y from one of the locations to the other. Some participants can transfer units of X and Y from location B to location A, but not from location A to location B. The rest of the participants can transfer units of X and Y from location A to location B, but not from B to A. To transfer units, use the F4 key.

5 Trading Profits

A possible source of profits is from buying and selling X, Y, currency A, and currency B. Selling increases your cash on hand by the amount of the sale price. Buying reduces your cash on hand by the amount of the purchase. Thus, you can either gain or lose money on the purchase and resale of units.

6 Beginning of Period Inventories

All sellers begin each period with inventory of X and Y. All buyers begin each period with no X or Y. All participants begin each period with a large inventory of either currency A or currency B. Beginning of period inventories are the same for each market period.

7 Note on the System

You can imagine yourself at one of the two locations with an inventory of that location's currency. Should you find it advantageous, you could buy the currency of the other

location and use it to buy X and/or Y there instead of buying X and/or Y at your location.

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